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TRANSPORTATION LABORATORY

RESEARCH REPORT

End-Result Asphalt Concrete Compaction Study

FINAL REPORT

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16 ABSTRACT

The significant increase in AC production rates during recent years has made it very difficult for an Inspector to stay abreast of the Contractor's operations. Also, the use of "method" specifications for AC compaction not only requires a considerable amount of inspection effort but also discourages Contractor innovation. Because the adoption of an end-point AC compaction specification would offer the possibility of alleviating both of these problems, this study was accomplished. In-situ AC densities were measured on three projects under actual field inspection conditions using a nuclear gage. On one of the projects, AC permeabilities were also measured. It was concluded that adoption of the 1975 method specification apparently resulted in higher AC densities than achieved under the 1973 specifications. It was also concluded that use of an end-point specification for AC density involving measurements at ten randomly selected locations per 48,000 square feet of paving would provide adequate quality assurance for a "lot" of this size. Because this approach would decrease inspection costs and permit more Contractor innovation, trial use of an end-point specification incorporating these findings on 6 to 10 contracts will be recommended.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

January 1977

TL No. 643130

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

END-RESULT ASPHALT CONCRETE COMPACTION STUDY

Study made by ..... Roadbed and Concrete Branch

Under the Supervision of ..... D. L. Spellman

Principal Investigator ..... Robert N. Doty

Co-Principal Investigator ..... James A. Cechetini

Report Prepared by ..... James A. Cechetini
and
Robert N. Doty

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

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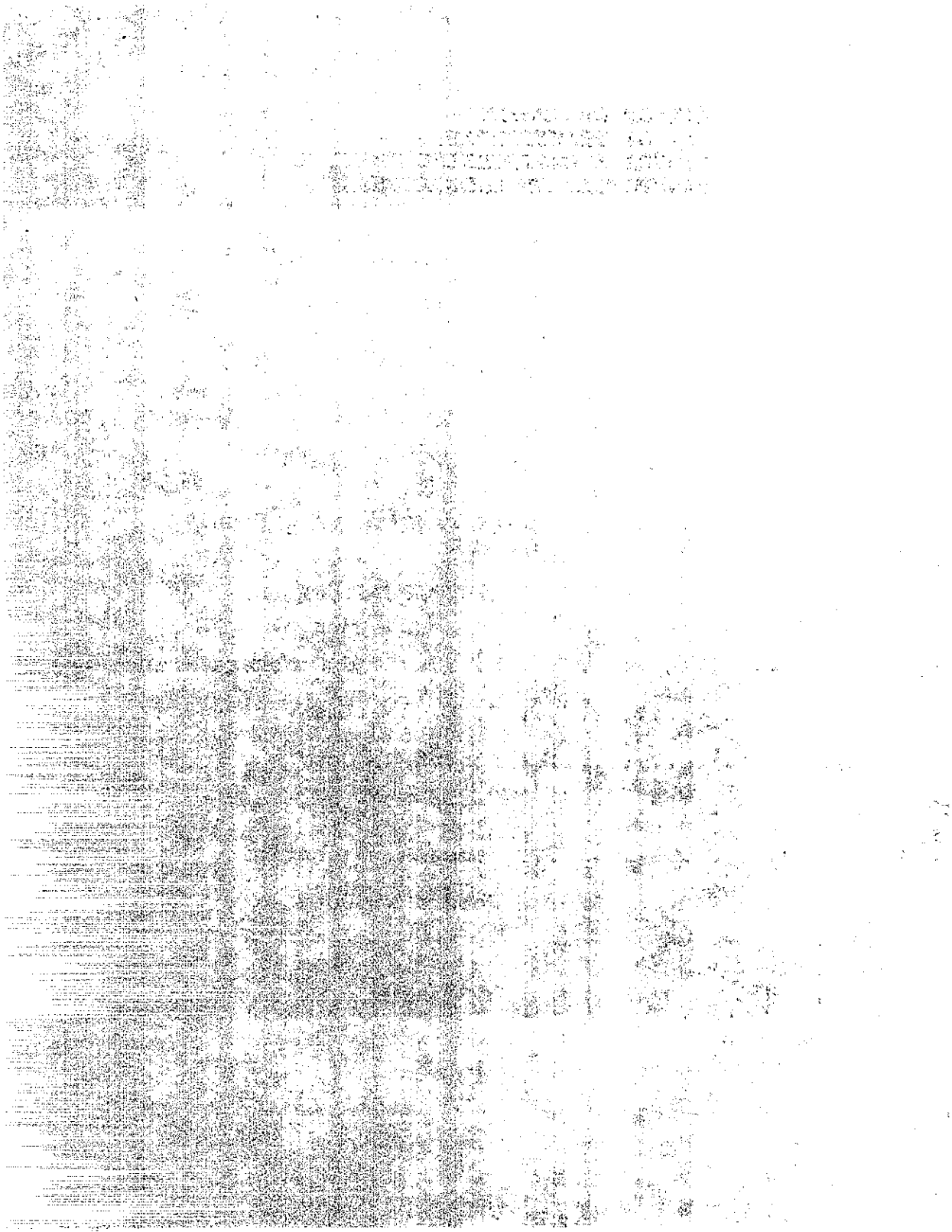
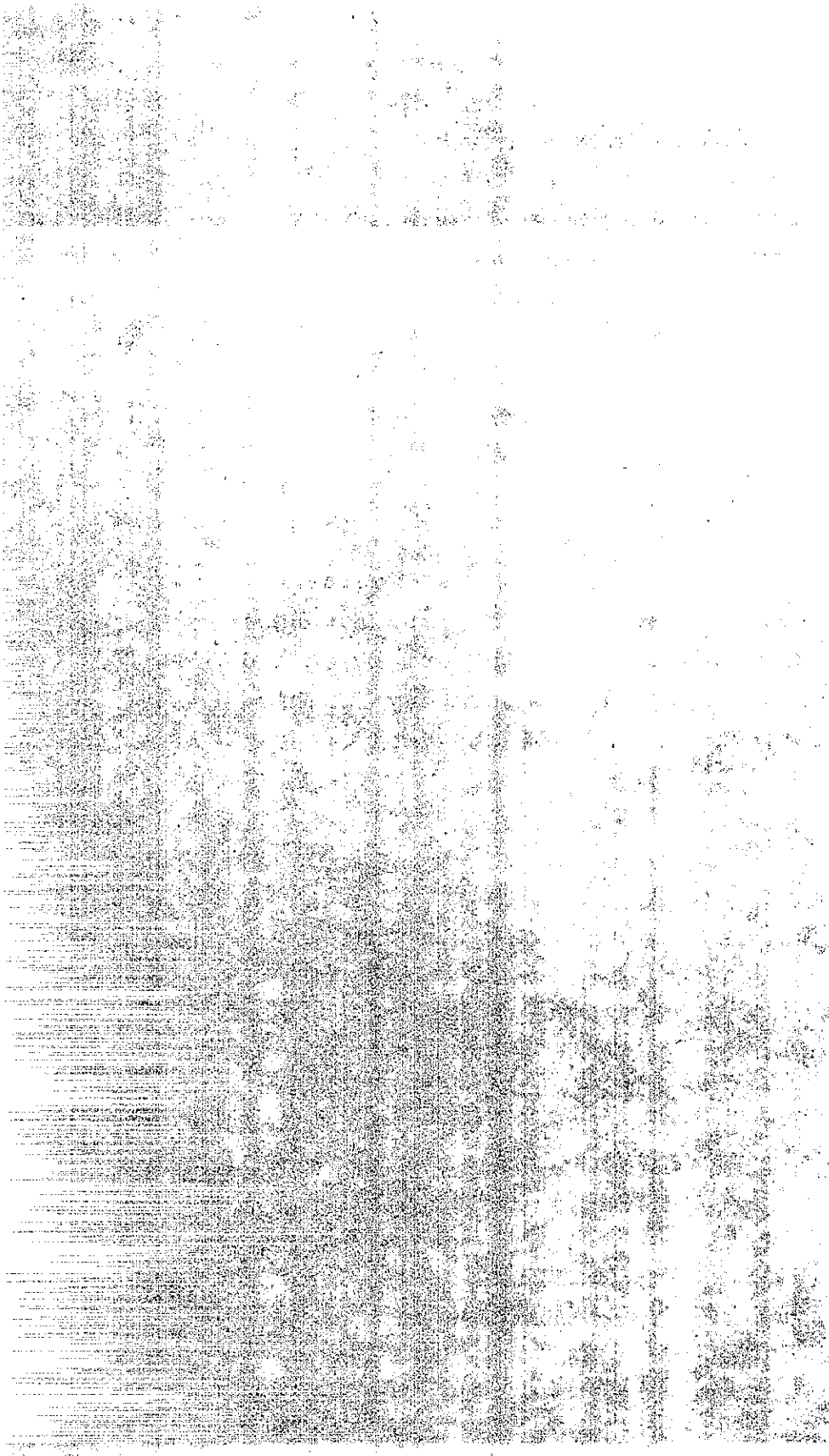
Attachment



ACKNOWLEDGEMENTS

This is the final report for a study titled "Review and Evaluate the Use of an End-Result Compaction Requirement for Asphalt Concrete Pavement". The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

The authors wish to express their appreciation to Resident Engineers Frank Pappa, Gorden Gibbs, and M. Maynard for their cooperation in obtaining the data for this investigation and to Charles Frazier of the Transportation Laboratory for his assistance with the statistical analysis of the data.



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INTRODUCTION

A "method" specification for compaction of asphalt concrete has been used by the California Department of Transportation for a number of years. This type of specification not only limits the type of compactors that can be used but also requires the contractor to follow a given compaction procedure. The results of a study completed in 1974 titled "Compaction of Asphalt Concrete Pavements" (1,2,3,4) revealed that the method specification previously used by Caltrans did not generally result in the compaction considered necessary to obtain the desired life expectancy from asphalt concrete pavements. To improve this situation, a recommendation was made to (1) increase the required number of breakdown coverages from one to three (12 ton tandem) and (2) to permit the contractor to use a compactor approved per Test Method No. Calif. 913 if operated in accordance with the conditions for which it was tested such as roller speed, vibration amplitude and frequency, and the number of coverages applied. This recommendation was implemented in the January 1975 California Standard Specifications. However, even this new specification is, in part, a method specification and, as such, requires continuous inspection of the compaction operation to ensure specification compliance. This problem was the primary reason for developing a method of quality assurance with respect to AC density permitting more innovation by the contractor, and requiring less construction inspection time.

This report contains the density test results from the three projects investigated. Permeability measurements are also presented and discussed.

CONCLUSIONS

The findings of this limited study were used as the basis for the following conclusions:

1. Asphalt concrete pavement constructed under the January, 1975 Standard Specifications will equal or exceed the desired 95 percent relative compaction considerably more often than will pavement constructed under the January, 1973 Standard Specifications.

2. In most cases, one technician cannot complete ten randomly located nuclear AC density measurements per 500 lineal feet of paving and keep up with the paving operation.

3. Nuclear AC density measurements taken at ten randomly selected locations within a 4,000-foot long 12-foot wide pavement surface provide sufficient control of AC compaction operations.

4. The results of AC permeability tests should not be used as a measure of AC density and/or relative compaction.

IMPLEMENTATION

The use of specifications requiring at least 95 percent relative compaction when measured at ten randomly selected locations within each "lot" of 50,000 square feet of AC paving or a half-day run, whichever is less, will be recommended for 6 to 10 contracts statewide.

DISCUSSION

General

The objectives of this study were to determine the number of nuclear density tests that could be made by a technician in an eight hour work period to establish a reasonable lot size for control and to evaluate the water permeability test (Test Method No. Calif. 341-A) as a replacement for relative compaction as suggested in a report by Zube (5).

The tentative procedure on those projects selected for trial was: (a) to complete ten randomized nuclear density measurements in every 500 foot length of newly constructed asphalt concrete pavement and (b) to complete water permeability tests (Test Method No. Calif. 341-A) at the locations selected for the nuclear tests.

Project "A"

The first project on which these procedures were tried was located on Interstate 680 near San Jose, California. A California Type A 3/4-inch maximum asphalt concrete mix containing 5.2% ± AR 4000 asphalt was being placed with a Barber-Greene paver at a speed of 35-40 feet per minute. The temperature of the AC in the 0.18-foot thick 24-foot wide mat immediately behind the paver ranged from 250° to 280°F. The compaction procedure consisted of one breakdown coverage with a 12-ton tandem, three coverages with a pneumatic, and a final coverage with an 8-ton tandem. This procedure complied with the requirements of the January, 1973 Standard Specifications which were in effect for this Contract.

On the first day of paving, the contractor had operational problems with his hot plant so only about 500 tons of asphalt concrete was delivered to the jobsite; this was sufficient for a section 1,500 feet long and 24 feet wide. In this section, ten density measurements were made in each 500 foot subsection for a total of 30 density readings. The results are presented in Table 1.

TABLE 1

AC Density (Pounds per Cubic Foot)

Project A

Location No.	Stations 817+00 to 822+00	822+00 to 827+00	827+00 to 832+00
1	140	143	147
2	139	142	142
3	142	141	140
4	139	143	139
5	140	141	139
6	136*	142	137
7	136*	142	139
8	139	143	138
9	138	144	146
10	140	144	144
$\bar{X}$	139	143	141
σ	1.86	1.00	3.48
Rel. Comp.	92.6%	95.0%	94.0%

*Less than 92% relative compaction, with relative compaction defined as the ratio of the in-place density of the asphalt concrete pavement to the test maximum density (average of five waxed specimens) of the same asphalt concrete mix when compacted with the California Kneading Compactor per Test Method No. Calif. 304.

As shown, only one of the three subsections passed the tentative requirement of 95 percent relative compaction. Rain prevented completing the water permeability tests the following day. On the second day of paving, approximately 2,000 tons of asphalt concrete were placed representing approximately 1.1 miles. Before the first series of ten density measurements representing a 500 foot section were completed, it became apparent that one man would not be able to make ten density measurements in every 500 feet of completed pavement in an eight hour day. Further testing indicated that one technician could complete approximately 50 nuclear density readings to evaluate the entire day's paving.

The following morning, water permeability tests were completed and the profile index measured. The density and water permeability test results are shown in Table 2 and Figure 1. The profile index for the one mile test section was 4.5 inches per mile.

The results presented in Tables 1 and 2 generally showed that the relative compaction was lower than the tentative specification limit of 95 percent minimum. However, these density results are approximately the same as those previously reported (1,2,3) when the rolling procedure included in the 1973 Standard Specifications was used. The water permeability results were so widely scattered that this test was dropped as a quality assurance test for determining relative compaction; however, permeability is an important factor in asphalt durability and further work on this property is warranted.

Project "B"

The second project studied was located on State Route 65 near Sheridan, California. The asphalt concrete was a 3/4-inch maximum Type B mix containing 4.9% ± AR 8000 asphalt. A 12-foot wide,

TABLE 2

AC Density and Permeability

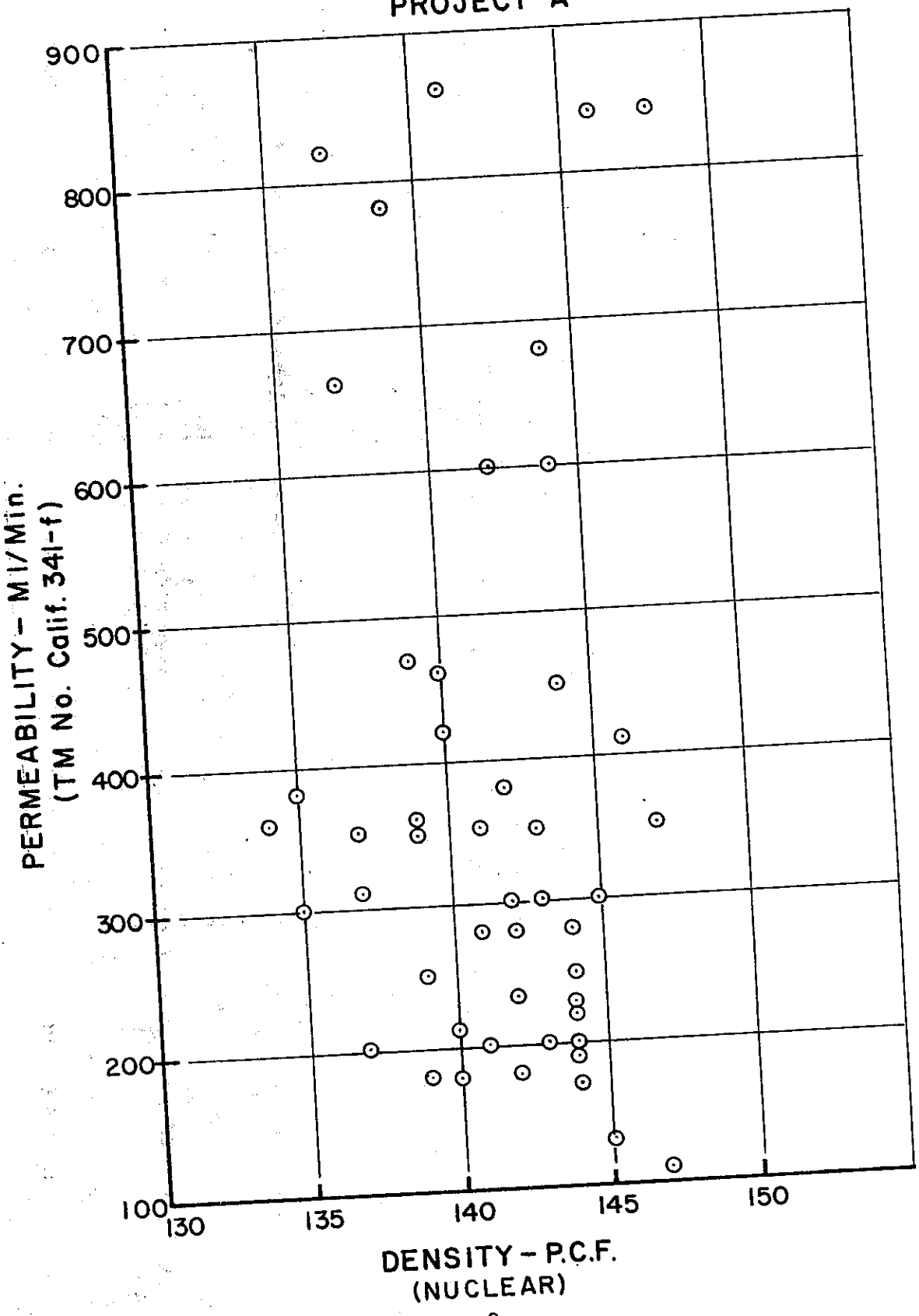
Project A

Location No.	STATION 790+40 to 795+40 P.C.F.	Ml/Min	799+00 to 804+00 P.C.F.	Ml/Min	810+00 to 815+00 P.C.F.	Ml/Min	828+00 to 833+00 P.C.F.	Ml/Min	833+00 to 838+00 P.C.F.	Ml/Min
1	144	230	135*	300	143	300	144	200	142	290
2	144	190	144	450	134*	360	139	250	142	180
3	137*	200	142	300	142	230	144	170	141	200
4	142	600	144	250	141	350	137*	660	139	360
5	145	300	139	180	147	350	148	840	147	110
6	142	380	140	420	141	350	145	130	139	350
7	143	350	146	840	141	280	140	180	137*	350
8	144	680	141	860	137*	820	140	210	140	420
9	146	410	140	460	139	780	144	600	139	470
10	143	200	135*	380	144	280	137*	310	144	210
$\bar{X}$	143	354	141	444	141	410	142	355	141	294
σ	2.45	171	3.68	232	3.77	210	3.71	242	2.91	116
Rel. Comp.	95.3%		94.0%		94.0%		94.7%		94.0%	

Figure 1

A.C. PERMEABILITY VS DENSITY

PROJECT A



0.20-foot thick leveling course was being placed using a Blaw-Knox paver. The average temperature of the windrowed mix immediately in front of the paver was 260°F. The compaction operation consisted of breakdown with a 16-ton vibratory, double drum roller. The final coverage was made with an 8 ton static tandem roller. This procedure complied with the requirements of the January, 1975 Standard Specifications.

Nuclear density measurements on the completed asphalt concrete mat were taken between Stations 446+00 and 473+00 (2 hours of production). A 500 foot test section was randomly selected within the 2700 foot section and 30 density measurements were completed within this section. Thirty additional density tests were completed at randomly selected locations within the entire 2700 feet. The test data is presented in Table 3 as three groups of ten for each "lot".

TABLE 3

AC Density (P.C.F.)

Project B

	500 Ft Test Section			2700 Ft. Test Section		
1	139	142	141	141	141	141
2	140	136	138	139	138	137
3	140	137	141	140	135	135
4	138	141	141	141	141	141
5	140	138	135	141	136	138
6	137	134	138	141	135	137
7	141	138	137	143	140	142
8	143	134	138	141	138	138
9	140	138	141	139	142	141
10	142	142	142	140	141	141
$\overline{X}$	140	138	139	141	139	139
σ	1.16	2.94	2.30	1.17	2.67	2.38
Rel Comp	96.6%	95.2%	95.9%	97.2%	95.9%	95.9%

It is interesting to note, when comparing the results in Tables 1 and 2 (1973 Specifications) with results from Table 3 (job constructed under 1975 Specifications), that all but one section shown in Tables 1 and 2 either failed to meet the 95 percent average relative compaction or contained one or more individual test results below 92 percent relative compaction while all the sections shown in Table 3 had a relative compaction greater than 95 percent.

The following statistical analysis of the test data contained in Table 3 indicates that the larger area can be characterized with the same degree of confidence as the smaller area using 30 randomized tests for each.

Using the formulas C.L. = $\frac{\hat{\sigma}}{\sqrt{N}} \times t\ (1 - \frac{\alpha}{2})$ and $\hat{\sigma} = \sqrt{\frac{\Sigma X^2 - N\ (\overline{X}^2)}{N - 1}}$

The following confidence limits (C.L.) were calculated for an N=30:

	500 Ft. Test Section	2700 Ft. Test Section
$\overline{X}$	139.067 PCF	139.467 PCF
$\hat{\sigma}$	2.45 PCF	2.26 PCF
95% C.L.$_{\overline{x}}$	$\pm$0.91 PCF	$\pm$0.84 PCF
99% C.L.$_{\overline{x}}$	$\pm$1.23 PCF	$\pm$1.13 PCF

This data was analyzed further to determine the effect of reducing the number of density measurements from 30 to 10 with the following results:

	500 Ft. Test Section	2700 Ft. Test Section
$\overline{X}$	139.07 PCF	139.47 PCF
$\hat{\sigma}$	2.45 PCF	2.26 PCF
95% C.L.$_{\overline{x}}$	$\pm$1.75 PCF	$\pm$1.61 PCF
99% C.L.$_{\overline{x}}$	$\pm$2.52 PCF	$\pm$2.26 PCF

These results indicated that the number of randomly selected test locations could be reduced to ten for a "lot" of 32,400 square feet and still maintain a reasonable measure of quality control.

Project "C"

The third project tested was located on Interstate 15 near Temecula. Type B mix containing 3/4-inch maximum aggregate and 5.3% ± AR 4000 asphalt was being placed 0.20-feet thick in a twelve-foot wide pass. An approved vibratory roller was again used for breakdown compaction and, with the vibrating units turned off, as the finish roller. The AC mat temperature at the beginning of the breakdown compaction was 280°F.

The main objective on this project was to determine if the number of density measurements could be reduced from 30 to 10, under actual field conditions.

After the contractor had completed an 0.8 mile section (about a 3 hour production) nuclear density measurements were made throughout the entire 0.8 mile at 30 randomly selected locations. Ten additional tests, also at randomly selected locations, were made within the same 0.8 mile. The density results are shown in Table 4.

TABLE 4

AC DENSITY (P.C.F.)

Project C

(N)		(N)		(N)		(N)	
1	147	11	146	21	148	1	151
2	149	12	146	22	149	2	147
3	151	13	149	23	144	3	147
4	150	14	146	24	146	4	146
5	148	15	148	25	146	5	147
6	147	16	150	26	150	6	149
7	151	17	148	27	149	7	148
8	149	18	147	28	151	8	146
9	150	19	150	29	152	9	148
10	149	20	150	30	150	10	148
				$\overline{X}$	148.5	$\overline{X}$	147.7
				$\hat{\sigma}$	1.92	$\hat{\sigma}$	1.49

These data were then used to calculate confidence limits as follows:

30 Tests

$\overline{X}$ = 148.5 95% CL $_{\overline{x}}$ = $\pm$ 0.71 PCF

$\hat{\sigma}$ 1.92 99% CL $_{\overline{x}}$ = $\pm$ 0.97 PCF

10 Tests

$\overline{X}$ = 147.7 95% CL $_{\overline{x}}$ = $\pm$ 1.07 PCF

$\hat{\sigma}$ 1.494 99% CL $_{\overline{x}}$ = $\pm$ 1.54 PCF

From the above analysis, it was concluded that 10 nuclear density measurements at randomly selected locations would be sufficient to control a section of pavement, or lot, approximately 4,220 feet long and 12 feet wide (50,640 square feet) within $\pm$2 P.C.F. of the true mean with a confidence limit of 95 percent.

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